Neutrino Flux At Detector

- Neutrino beam is much wider than detector
  - Angular spread in decays: can't control
  - Angular divergence of muon beam
- Larger muon beam divergence, smaller flux
  - Narrow muon beam maximizes flux
  - Uncertainty in muon divergence $\longrightarrow$ uncertainty in flux
  - If decay divergence dominates muon divergence
    - ⋆ Narrowing muon divergence provides little benefit
    - ⋆ Lower uncertainty in flux
- Larger event rates
  - Small statistical uncertainty (~ 0.001 relative)
  - Requires low flux uncertainty

Computing Flux

- Flux is convolution of muon angular distribution with decay angular distribution

$$\rho(\theta_x, \theta_y) = \int \rho_{\mathrm{Muon}}(\theta_x - \theta'_x, \theta_y - \theta'_y)\rho_{\mathrm{Decay}}(\theta'_x, \theta'_y)\, d\theta'_x\, d\theta'_y$$

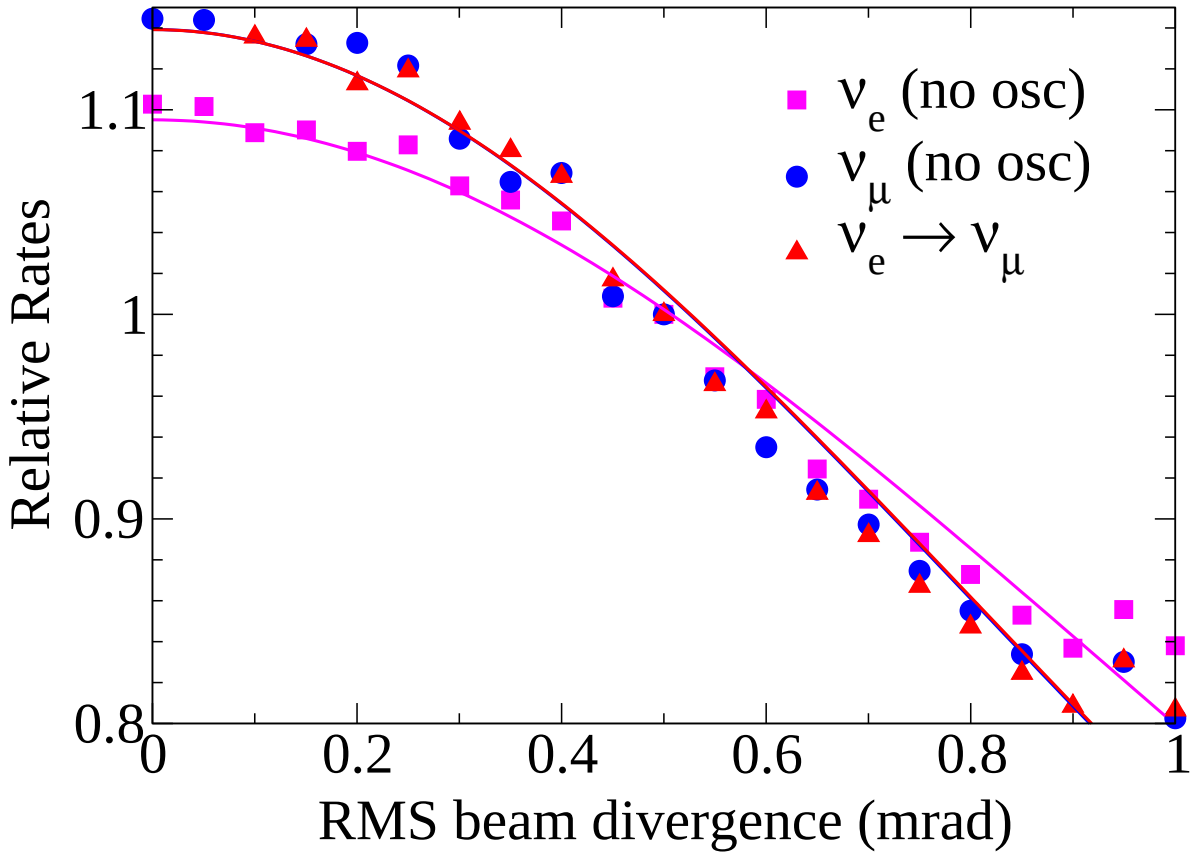
- $N\, d\Omega_{\mathrm{Detector}}\rho(0,0)$ is flux on detector
- If both Gaussian, muon beam σ_x, σ_y, decays σ_0

$$\frac{\phi(\sigma_x, \sigma_y, \sigma_0)}{\phi(0,0,\sigma_0)} = \frac{1}{\sqrt{1+\frac{\sigma_x^2}{\sigma_0^2}}\sqrt{1+\frac{\sigma_y^2}{\sigma_0^2}}}$$

- Uncertainty in flux comes from taking derivates of this with respect to σ_x, σ_y

Fitting Model Parameters

- Monte-Carlo calculation of event rates at detector as a function of muon beam divergence (Crisan & Geer)



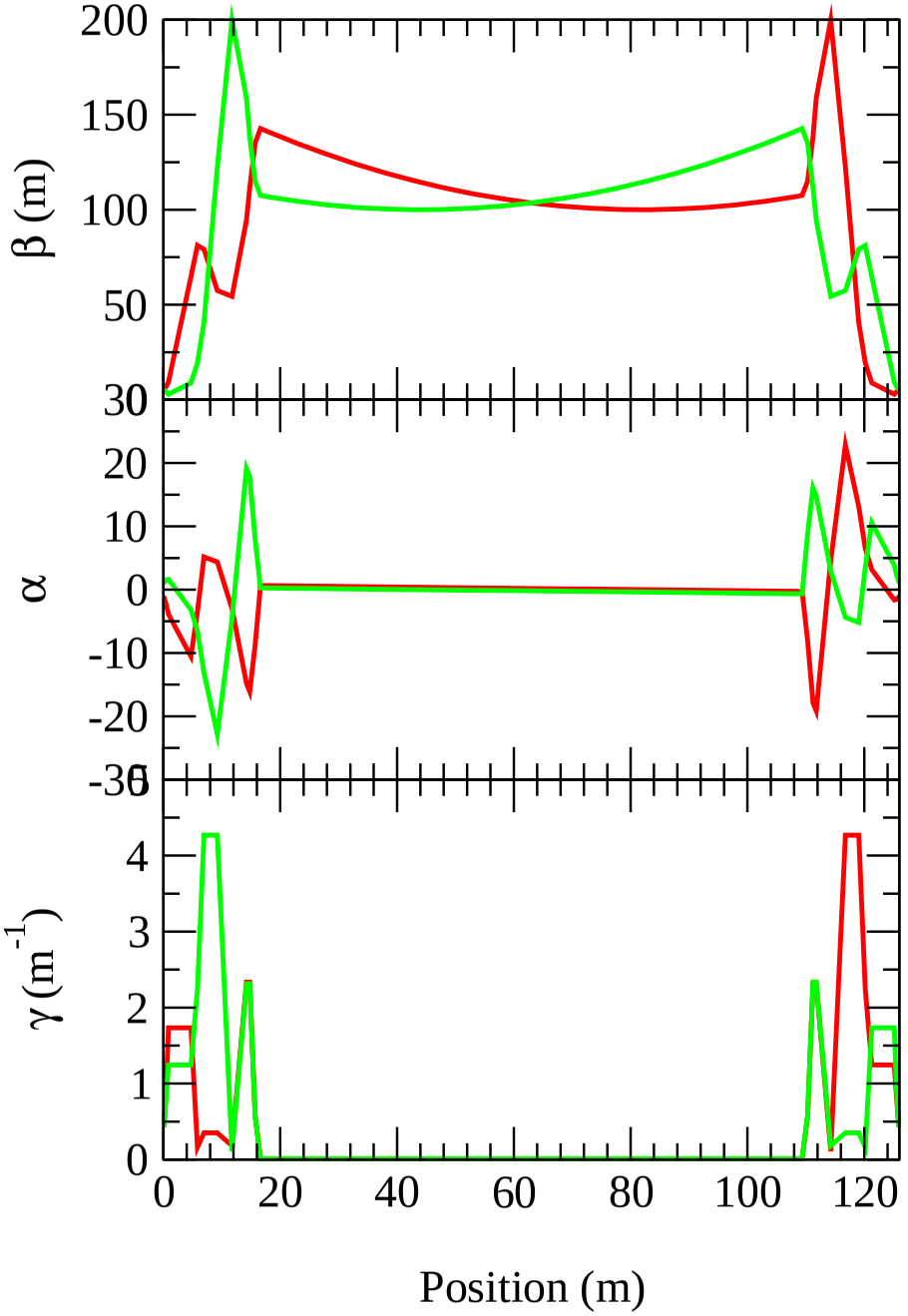
- Fit: $\sigma_0 = 0.42/\gamma$
  - Energy-weighted cross section
- Uncertainty: slope
  - Near zero divergence: small slope
  - Slope decreases to zero linearly
  - Larger divergence: larger slope, despite smaller flux!

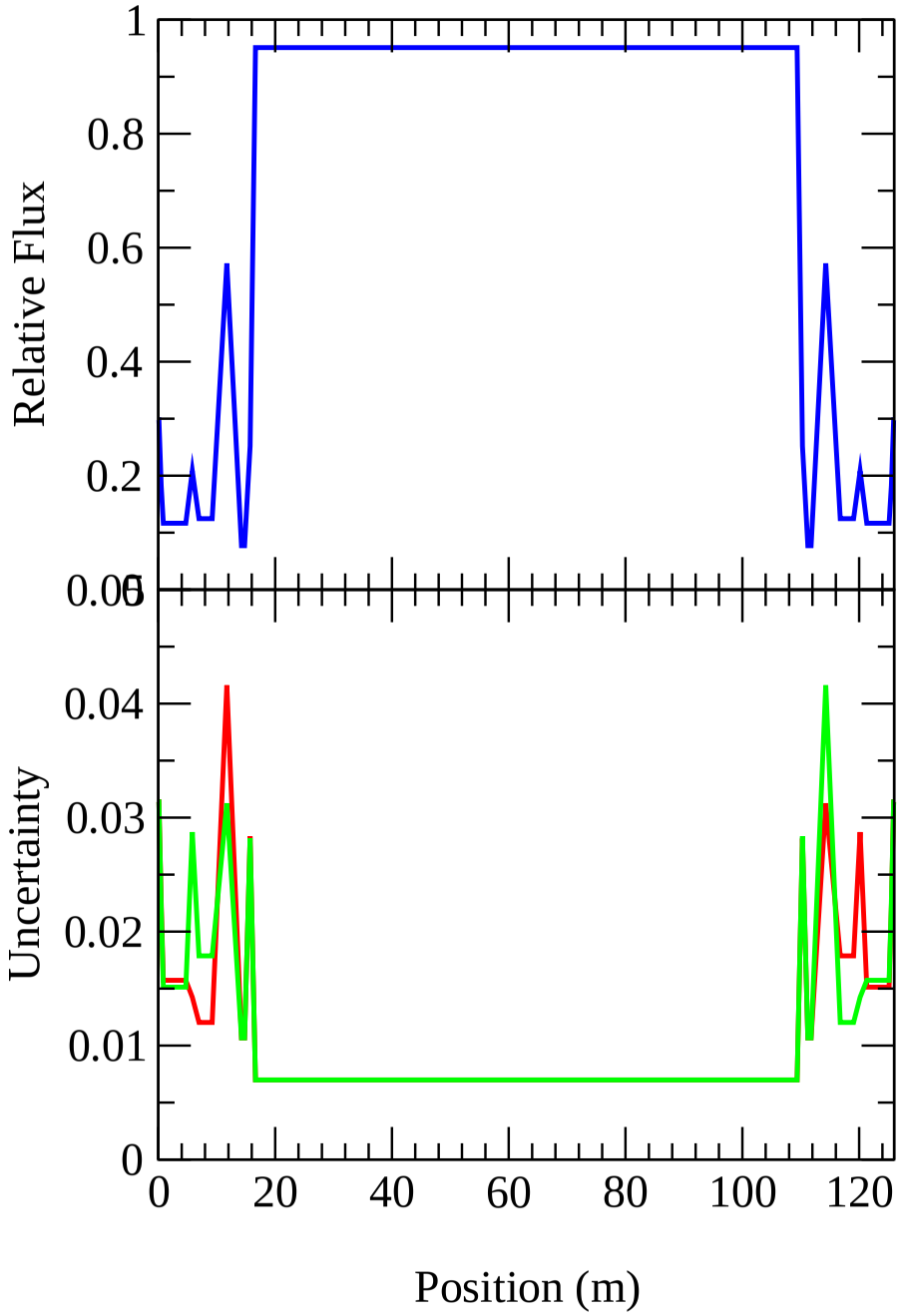
Production Straight

- Divergence is $\sqrt{\gamma\epsilon}$
  - $\gamma = (1 + \alpha^2)/\beta$
- Large divergence at ends
  - Smaller β
  - Large α
    - ⋆ Required to make β rise quickly
- Long drift in middle of straight
  - Keeps α down, reducing γ
- Larger divergence leads to
  - Lower flux
  - Higher uncertainty

Analysis

- Too must uncertainty coming from ends
  - Very little flux comes from there
  - Insert bends so they aren't pointed toward detector
    - ⋆ Very little loss: 8%
    - ⋆ Required bend: $\approx$ 29 mrad.
    - ⋆ Only 25% of muons decaying toward detector, not 35%
- Uncertainty from middle still too high: 1% (want 0.1%???)
  - Assumed uncertainty in σ_θ of 15%
    - ⋆ Make better measurement of muon beam
    - ⋆ Detectors placed in beam
    - ⋆ Electron backgrounds
  - Measure neutrino beam (Norem)
    - ⋆ Hodoscopes in a tunnel a couple hundred meters downstream
    - ⋆ Need several to get angular distribution
    - ⋆ Too close to source for one hodoscope to give angular distribution
  - Need high accuracy current measurement also


β (m)
α
γ (m-1)
Position (m)


Relative Flux
Uncertainty
Position (m)